

40 CFR 60.195

Location: METHOD 14

Line: 2

Run #: 1

Start Date: 1/12/2021

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40 CFR 60.195 Emission rate of total fluorides from potroom groups

$$E_p = [(C_s Q_{sd})_1 + (C_s Q_{sd})_2] / (P K) = \left[\frac{(C_s Q_{sd})_1}{P K} \right] + \left[\frac{(C_s Q_{sd})_2}{P K} \right] = (E_p)_1 + \left[\frac{(C_s Q_{sd})_2}{P K} \right]$$

E_p = Emission rate of total fluorides from a potroom group = 1.4 lbs/ton

$(E_s)_2$ = Emission rate of total fluorides from a secondary control system or roof monitor effluent gas = 1.1 lbs/ton

$(E_p)_1$ = Emission rate of total fluorides for primary control system effluent gas = 0.176 lbs/ton

$(C_s)_2$ = Concentration of total fluorides from secondary control system or roof monitor effluent gas = 0.020 mg/SCF

Q_{sd} = Average volumetric flow from roof monitor at standard conditions on a dry basis = 236,378,265 SCF/hr

P = Aluminum production rate = 9.58 ton/hr

K = Conversion factor = 453,600 mg/lb

1 = Subscript for primary control system effluent gas

2 = Subscript for secondary control system or roof monitor effluent gas

Emission rate of total fluorides from sample duct as shown in ERT

Calculations do not include the volumetric flow from the roof monitor. These are the numbers calculated in the ERT.

$(E_s)_2$ = Emission rate of total fluorides from the sample duct = 4.15E-04 lbs/ton

$(C_s)_2$ = Concentration of total fluorides from secondary control system or roof monitor effluent gas = 3.07E-04 grains/SCF

$(C_s)_2$ = Concentration of total fluorides from secondary control system or roof monitor effluent gas = 3.97E-03 lbs/hr

Q_{sd} = Average volumetric flow in the sample duct at standard conditions on a dry basis = 1,507 SCFM

Method 2 and 3 Calculations

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Equation 2-5: Molecular Weight of Stack Gas

$$M_s = M_d (1 - B_{ws}) + 18.0 B_{ws}$$

18.0	=	Molecular weight of water	=	18.0 lb/lb-mole
M_d	=	Dry molecular weight of sample gas	=	28.83 lb/lb-mole
B_{ws}	=	Water vapor in the gas stream, proportion by volume	=	-0.0017
M_s	=	Molecular weight of sample gas/ wet basis	=	28.85 lb/lb-mole

Equation 2-6: Absolute stack gas pressure

$$P_s = P_{bar} + \left[\frac{P_g}{13.6} \right]$$

P_{bar}	=	Barometric pressure at the sampling (or measurement) site	=	30.04 in. Hg
P_g	=	Stack static pressure	=	-0.54 in. Water
13.6	=	Conversion factor (Specific gravity of mercury)	=	13.6 in. Water/in. Hg
P_s	=	Absolute stack pressure (Pbar + Pg)	=	30.00 in. Hg

Equation 2-8: Absolute stack temperature

$$T_s = 460 + t_s$$

t_s	=	Stack temperature	=	69.2 deg. F
T_s	=	Absolute stack temperature for English	=	529.2 deg. R

Equation 2-9: Average Stack Gas Velocity

$$v_s = K_p C_p \sqrt{\Delta p_{avg}} \sqrt{\frac{(T_s + 460)}{P_s M_s}}$$

K_p	=	Velocity pressure constant	=	$85.49 \frac{ft}{sec} \left[\frac{(lb/lb-mole)(in.Hg)}{(^{\circ}R)(in.H_2O)} \right]^{\frac{1}{2}}$
C_p	=	Pitot tube coefficient	=	0.84
M_s	=	Wet molecular weight of sample gas, wet basis	=	28.9 lb/lb-mole
P_s	=	Absolute sample gas pressure	=	30.00 in. Hg
T_s	=	Average sample gas temperature	=	69.2 deg. F
$\sqrt{\Delta P}$	=	Average square root of velocity head of stack gas	=	0.36 in. Water

Method 2 and 3 Calculations

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	460	=	Deg. F to deg. R conversion constant			=	460
	v_s	=	Average stack gas velocity			=	20.04 ft/sec

Equation 2-10: Average Stack Gas Dry Volumetric Flow Rate

$$Q_{sd} = 3600(1 - B_{ws})v_s A \left[\frac{T_{std} P_s}{T_{s(avg)} P_{std}} \right]$$

B_{ws}	= Water vapor in the gas stream, proportion by volume		= -0.002
v_s	= Average stack gas velocity		= 20.04 ft/sec
A	= Cross-sectional area of stack		= 1.25 sq. ft.
T_{std}	= Standard absolute temperature		= 528 deg. R
P_s	= Absolute stack gas pressure		= 30.00 in. Hg
T_s	= Absolute stack temperature		= 529.20 deg. R
P_{std}	= Standard absolute pressure		= 29.92 in. Hg
Q_{sd}	= Dry volumetric stack gas flow rate corrected to standard conditions		= 90425.5 dscf/hr

Equation 3-1: Dry Molecular Weight

$$M_d = 0.440(\%CO_2) + 0.320(\%O_2) + 0.280(\%N_2 + \%CO)$$

$\%CO_2$	= Percent CO2 by volume, dry basis		= 0.1
$\%O_2$	= Percent O2 by volume, dry basis		= 20.8
$\%N_2$ and $\%CO$	= Percent N2 and CO by volume, dry basis		= 79.2
0.280	= Molecular weight of N2 or CO, divided by 100		= 0.280
0.320	= Molecular weight of O2, divided by 100		= 0.320
0.440	= Molecular weight of CO2, divided by 100		= 0.440
M_d	= Dry molecular weight of sample gas		= 28.83 lb/lb-mole

Method 4 Calculations

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Equation 4-1: Volume of water vapor condensed

$$V_{wc(std)} = \frac{(V_f - V_i) \rho_w R T_{std}}{P_{std} M_w} = K_1 (V_f - V_i)$$

Equation 4-2: Volume of water vapor collected in silica gel

$$V_{wsg(std)} = \frac{(w_f - w_i) R T_{std}}{P_{std} M_w} = K_2 (w_f - w_i)$$

Equation 4-3: Sample gas volume

$$V_{m(std)} = V_m Y \frac{P_m T_{std}}{P_{std} T_m} = K_3 Y \frac{V_m P_m}{T_m}$$

Equation 4-4: Moisture content

$$B_{ws} = \frac{V_{wc(std)} + V_{wsg(std)}}{V_{wc(std)} + V_{wsg(std)} + V_{m(std)}}$$

K_1	= 0.04707 for English units	= 0.04707 cu. ft./ml
K_2	= 0.04715 for English units	= 0.04715 cu. ft/g
K_3	= 17.64 for English units	= 17.64 deg. R/in. Hg
M_w	= Molecular weight of water	= 18.0 lb/lb-mole
P_m	= Absolute pressure (for this method, same as barometric pressure) at the dry gas meter	= 30.04 in. Hg
P_{std}	= Standard absolute pressure	= 29.92 in. Hg
R	= Ideal gas constant for English units	= 21.85 (in. Hg)(cu. ft.)/(lb-mole)(deg. R)
T_m	= Absolute temperature at meter	= 534.81 deg. R
T_{std}	= Standard absolute temperature	= 528 deg. R
V_m	= Dry gas volume measured by dry gas meter	= 963.31 dcf
$V_{m(std)}$	= Dry gas volume measured by dry gas meter, corrected to standard conditions	= 957.822 dscf

Method 4 Calculations

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$V_{wc(std)}$	=	Volume of water vapor condensed corrected to standard conditions	=	-4.65	scf
$V_{wsg(std)}$	=	Volume of water vapor collected in silica gel corrected to standard conditions	=	3.02	scf
V_f	=	Final volume of condenser water	=	2162.10	ml
V_i	=	Initial volume of condenser water	=	2260.90	ml
w_f	=	Final weight of silica gel	=	1175.10	g
w_i	=	Initial weight of silica gel	=	1111.10	g
B_{ws}	=	Water vapor in the gas stream, proportion by volume	=	-0.0017	= -0.17 %

Method 5 Calculations

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Equation 5-1: Volume of Dry Gas in Cubic Feet Sampled corrected to Standard Conditions, (dscf)

$$V_{m(std)} = K_1 V_m Y \frac{\left[P_{bar} + \frac{\Delta H}{13.6} \right]}{(460 + T_m)}$$

P_{bar}	= Barometric pressure at the sampling (or measurement) site	=	30.04 in. Hg
T_m	= Absolute average DGM temperature	=	74.8 deg. F
V_m	= Dry gas volume measured by the dry gas meter	=	963.315 dcf
Y	= Dry gas meter calibration factor (dimensionless)	=	0.998
ΔH	= Average pressure differential across the orifice meter	=	1.62 in. Water
K_1	= Standard temperature to pressure ratio (528/29.92)	=	17.647 deg. R/in. Hg
13.6	= Conversion factor (Specific gravity of mercury)	=	13.6 in. Water/in. Hg
460	= Conversion factor (deg. F to deg. R)	=	460
$V_{m(std)}$	= Dry gas volume measured by the dry gas meter, corrected to standard conditions	=	957.822 dscf

Equation 5-2: Volume of Water Vapor Condensed, (scf)

$$V_{w(std)} = \frac{V_{lc} \rho_w R T_{std}}{M_w P_{std}} = K_2 V_{lc}$$

V_{lc}	= Total Volume of liquid collected in impingers and silica gel	=	-34.8 ml
K_2	= Ideal gas conversion factor (cu. ft. water vapor/ml)	=	0.04707 cu. ft./ml
$V_{w(std)}$	= Volume of water vapor in the gas sample, corrected to standard conditions	=	-1.6 cu. ft.

Equation 5-3: Moisture Content, (dimensionless)

$$B_{ws} = \frac{V_{w(std)}}{V_{m(std)} + V_{w(std)}}$$

$V_{m(std)}$	= Dry gas volume measured by the dry gas meter, corrected to standard conditions	=	957.822 dscf
$V_{w(std)}$	= Volume of water vapor in the gas sample, corrected to standard conditions	=	-1.64 scf
B_{ws}	= Water vapor in the gas stream, proportion by volume	=	-0.0017 = -0.17 %

Method 5 Calculations

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Equation 5-4: Acetone Blank Concentration

$$C_a = \frac{m_a}{V_a \rho_a}$$

Equation 5-5: Acetone Wash Blank

$$W_a = C_a V_{aw} \rho_a$$

C_a	= Acetone blank residue concentration	=	2.5E-06	mg/mg
m_a	= Mass of residue of acetone after evaporation	=	0.40	mg
V_a	= Volume of acetone blank	=	200.0	ml
ρ_a	= Density of acetone (see label on bottle)	=	785.2	mg/ml
W_a	= Weight of residue in acetone wash	=	2.5E-01	mg
V_{aw}	= Volume of acetone used in wash	=	125.00	ml

Equation 5-6: Particulate concentration

$$c_s = (0.001 \text{ g / mg}) (m_n / V_{m(std)})$$

c_s	= Concentration of particulate matter in stack gas, dry basis, corrected to standard conditions	=	0.0000501	g/dscf
m_n	= Total amount of particulate matter collected	=	47.95	mg

Equation 5-7: Percent of Isokinetic sampling

$$I = \frac{100 T_s [K_3 V_{lc} + (V_m Y / T_m) (P_{bar} + \Delta H / 13.6)]}{60 \Theta v_s P_s A_n}$$

I	= Percent of Isokinetic sampling (train to duct)	=	98.01	%
K_3	= 0.002669 for English units	=	0.002669	(in. Hg)(cu.ft.) / (ml)(deg. R)
Θ	= Total sampling time	=	1395.00	min.
v_s	= Average stack gas velocity	=	20.04	ft/sec
T_s	= Absolute average stack gas temperature	=	529.2	deg. R
P_s	= Absolute stack gas pressure	=	30.04	in. Hg
A_n	= Cross-sectional area of nozzle	=	0.000581	sq. ft.

Method 5 Calculations

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Equation 5-8: Percent of Isokinetic sampling calculation from Intermediate values

$$I = \frac{100T_s V_{m(std)} P_{std}}{60T_{std} v_s \Theta A_n P_s (1 - B_{ws})} = \frac{K_4 T_s V_{m(std)}}{P_s v_s A_n \Theta (1 - B_{ws})}$$

I	= Percent of Isokinetic sampling (train to duct)	=	98.01	%
K_4	= 0.09450 for English units	=	0.09450	(in. Hg)(cu.ft.)/(ml)(deg. R)
Θ	= Total sampling time	=	1395.00	min.
v_s	= Average stack gas velocity	=	20.04	ft/sec

Emission rate of Particulate in lbs/hr

$$E_p = \frac{c_s}{7000} Q_{sd}$$

c_s	= Concentration of particulate matter in stack gas, dry basis, corrected to standard conditions	=	0.000880	grains/dscf
Q_{sd}	= Dry volumetric stack gas flow rate corrected to standard conditions	=	90426	dscf/hr
7000	= Conversion factor	=	7000	grains/lb
E_p	= Emission rate of particulate	=	29.71	lb/hr
	= Emission rate of particulate	=	3.10	lb/ton

Method 13A Calculations

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Equation 13A-1 (Gaseous): Gaseous fluoride in sample

$$F_g = 10^{-3} \frac{V_g}{A_g} \frac{V_{gd}}{A_{gd}} (\mu\text{g } F)$$

V_g	= Total volume of gaseous F sample, after final dilution	=	1000 ml
V_{gd}	= Volume of gaseous distillate as diluted	=	250 ml
A_g	= Aliquot of gaseous sample added to still	=	50 ml
A_{gd}	= Aliquot of gaseous distillate taken for color development	=	25 ml
$\mu\text{g } F$	= Concentration from the calibration curve	=	42.0 ug
F_g	= Gaseous F in sample	=	12.31 mg

Equation 13A-1 (Particulate): Particulate fluoride in sample

$$F_p = 10^{-3} \frac{V_p}{A_p} \frac{V_{pd}}{A_{pd}} (\mu\text{g } F)$$

V_p	= Total volume of gaseous F sample, after final dilution	=	100 ml
V_{pd}	= Volume of gaseous distillate as diluted	=	250 ml
A_p	= Aliquot of gaseous sample added to still	=	10 ml
A_{pd}	= Aliquot of gaseous distillate taken for color development	=	15 ml
$\mu\text{g } F$	= Concentration from the calibration curve	=	43.4 ug
F_p	= Particulate F in sample	=	6.77 mg

Equation 13A-1: Total fluoride in sample

$$F_t = F_g + F_p$$

F_t	= Total F in sample	=	19.08 mg
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Equation 13A-2: Fluoride concentration in stack gas

$$C_s = \frac{F_t}{V_{m(std)}}$$

$V_{m(std)}$	= Dry gas volume measured by the dry gas meter, corrected to standard conditions	=	27.126 SCM
c_s	= Fluoride concentration in stack gas	=	0.703 mg/SCM

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Equation 14-1: Velocity in duct at sampling location

Since the duct at the sampling location is rectangular instead of circular, equation 14-1 must be modified to obtain equation 14-1m.

$$v_d = \frac{8(D_n)^2}{(D_d)^2} (v_m) \frac{1 \text{ min}}{60 \text{ sec}}$$

Equation 14-1m: Velocity in duct at sampling location modified for rectangular sampling duct and in ft/min

$$v_d = \frac{(8 \pi D_n^2) / 4}{A_d} (v_m)$$

$$v_d = \text{Velocity in duct at sampling location} = 833.52 \text{ ft/min}$$

$$D_n = \text{Diameter of a roof monitor manifold nozzle} = 1.5 \text{ ft}$$

$$A_d = \text{Area of duct at sampling location} = 1.25 \text{ sq.ft.}$$

$$\frac{(8 \pi D_n^2) / 4}{(A_d)} = 11.3097$$

$$v_m = \text{Average velocity of the air stream in the roof monitor as determined by the anemometer located at the center of the sampling manifold} = 73.7 \text{ ft/min}$$

Equation 2-9: Average Stack Gas Velocity

$$v_s = 60 * K_p C_p \sqrt{\Delta p_{avg}} \sqrt{\frac{(T_s + 460)}{P_s M_s}} \text{ ft/min}$$

$$v_s = K_p C_p \sqrt{\Delta p_{avg}} \sqrt{\frac{(T_s + 460)}{P_s M_s}} \text{ ft/sec}$$

$$v_s = \text{Average stack gas velocity} = 1202.37 \text{ ft/min}$$

$$v_s = \text{Average stack gas velocity} = 20.04 \text{ ft/sec}$$

$$K_p = \text{Velocity pressure constant} = 85.49 \frac{\text{ft}}{\text{sec}} \left[\frac{(\text{lb/lb-mole})(\text{in.Hg})}{(^{\circ}\text{R})(\text{in.H}_2\text{O})} \right]^{\frac{1}{2}}$$

$$C_p = \text{Pitot tube coefficient} = 0.84$$

$$M_s = \text{Wet molecular weight of sample gas, wet basis} = 28.9 \text{ lb/lb-mole}$$

$$P_s = \text{Absolute sample gas pressure} = 30.00 \text{ in. Hg}$$

$$t_s = \text{Average sample gas temperature} = 69.2 \text{ deg. F}$$

$$\sqrt{\Delta P} = \text{Average square root of velocity head of stack gas} = 0.36 \text{ in. Water}$$

$$460 = \text{Deg. F to deg. R conversion constant} = 460$$

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Isokinetic Sampling Check

$$\% \text{ Isokinetic (Manifold to Roof) } = \frac{v_s P_s (t_m + 460)}{v_d P_m (t_s + 460)}$$

$$\% \text{ Isokinetic (Manifold to Roof) } = 147.74 \%$$

$$v_s = \text{Average stack gas velocity (actual)} = 1202.37 \text{ ft/min}$$

$$v_d = \text{Velocity in duct at sampling location} = 833.52 \text{ ft/min}$$

Correction Factor for % Isokinetic (Manifold to Roof) greater than 120

$$\text{Correction Factor} = 1 + \frac{([\% \text{ Isokinetic (Manifold to Roof) }] - 120)}{200}$$

$$F_t = \text{Total fluoride} = 19.08 \text{ mg}$$

$$V_{m(std)} = \text{Dry gas volume measured by the dry gas meter, corrected to standard conditions} = 27.126 \text{ SCM}$$

$$\text{Correction factor calculated if \% Isokinetic (Manifold to Roof) is greater than 120} = 1.1387$$

$$c_s = \text{Fluoride concentration in stack gas (uncorrected)} = 0.703 \text{ mg/SCM}$$

$$c_s = \text{Fluoride concentration in stack gas (corrected when \% isokinetic (manifold to roof) is greater than 120\%)} = 0.801 \text{ mg/SCM}$$

Equation 14-3: Average volumetric flow from roof monitor at standard conditions on a dry basis

$$Q_{sd} = \frac{V_{mt} M_d P_m (T_{std}) A}{(t_m + 460^\circ)(P_{std})} \quad \text{SCFM} \quad Q_{sd} = \frac{V_{mt} M_d P_m (T_{std}) A}{(t_m + 460^\circ)(P_{std})} * 60 \quad \text{SCF/hr}$$

$$Q_{sd} = \text{Average volumetric flow from roof monitor at standard conditions on a dry basis} = 3939638 \text{ SCFM}$$

$$Q_{sd} = \text{Average volumetric flow from roof monitor at standard conditions on a dry basis} = 236378265 \text{ SCF/hr}$$

$$A = \text{Roof monitor open area} = 63868 \text{ ft}^2$$

$$v_{mt} = \text{Average velocity of air in the roof monitor} = 62.7 \text{ ft/min}$$

$$P_m = \text{Pressure in the roof monitor; equal to barometric pressure} = 30.00 \text{ in. Hg}$$

$$t_m = \text{Roof monitor temperature} = 80.1 \text{ deg. F}$$

$$M_d = \text{Mole fraction of dry gas} = 1.002$$

$$T_{std} = \text{Standard absolute temperature} = 528 \text{ deg. R}$$

$$P_{std} = \text{Standard absolute pressure} = 29.92 \text{ in. Hg}$$